

Cooling Singapore Digitale Zwillinge für die Satdtplanung

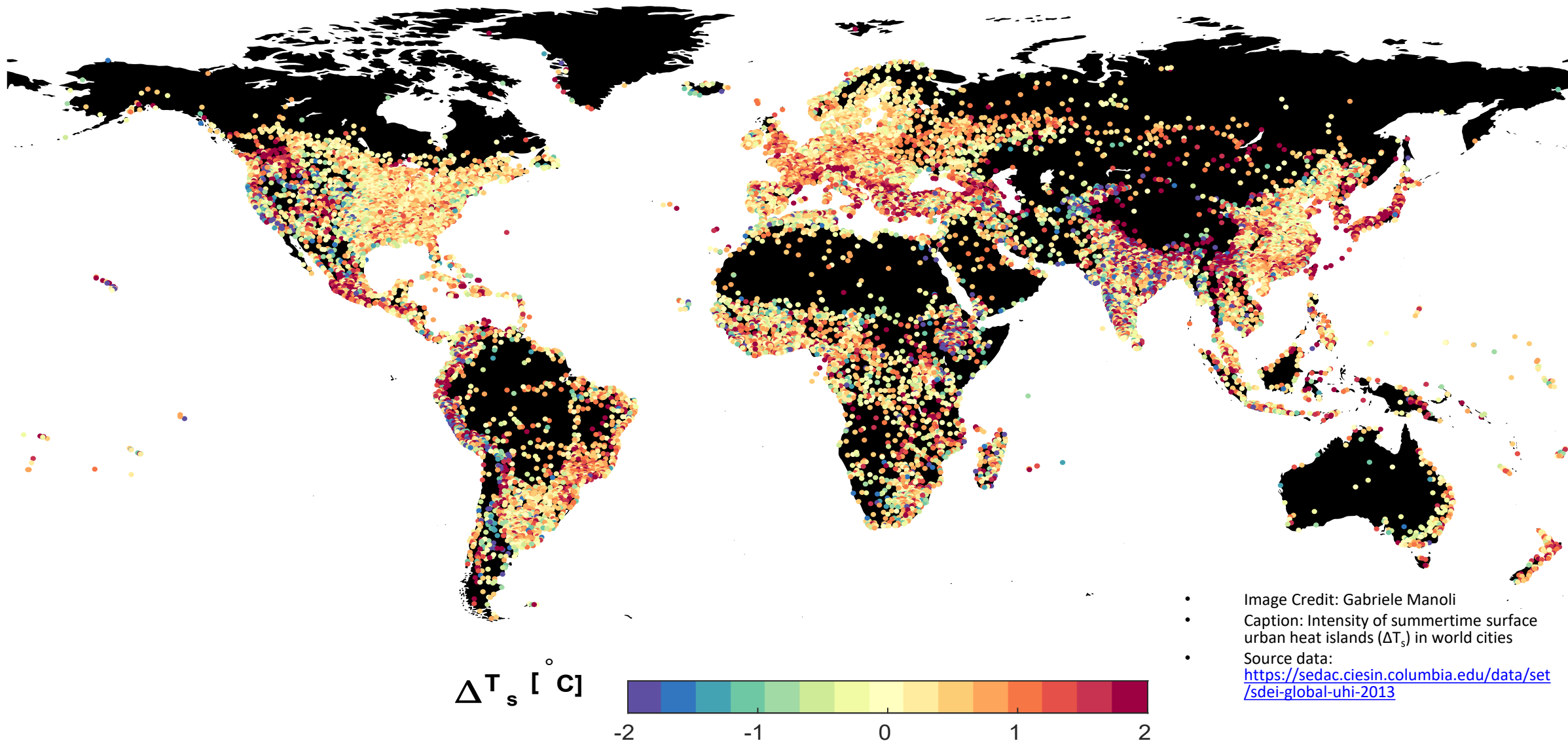
Prof. em. Dr. Gerhard Schmitt, ETH Zürich
Founding Director, Singapore-ETH Centre

VISIT...

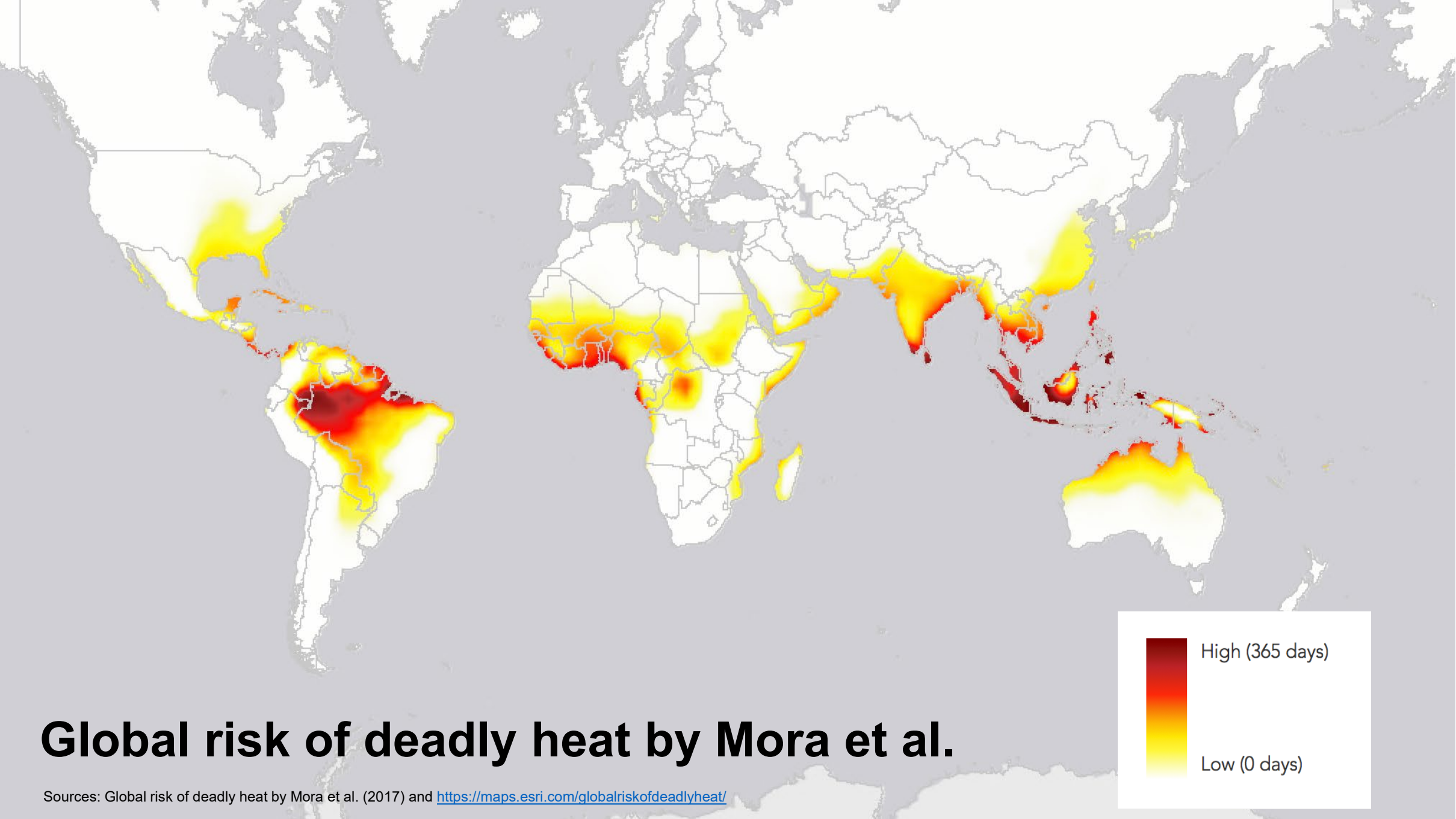
LANZAROTE
Caliente.COM



The Existential Threat of Global Warming



- Image Credit: Gabriele Manoli
- Caption: Intensity of summertime surface urban heat islands (ΔT_s) in world cities
- Source data:
<https://sedac.ciesin.columbia.edu/data/set/sdei-global-uhi-2013>



Global risk of deadly heat by Mora et al.

Sources: Global risk of deadly heat by Mora et al. (2017) and <https://maps.esri.com/globalriskofdeadlyheat/>

Cities

Causes and Victims of Climate
Change

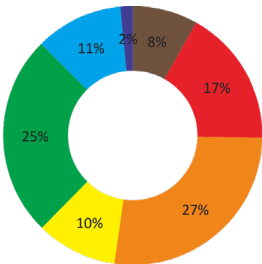
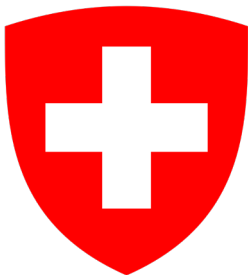


Digital Twin: Energy Switzerland

Dr. Matthias Berger, Singapore-ETH Centre, 2012.

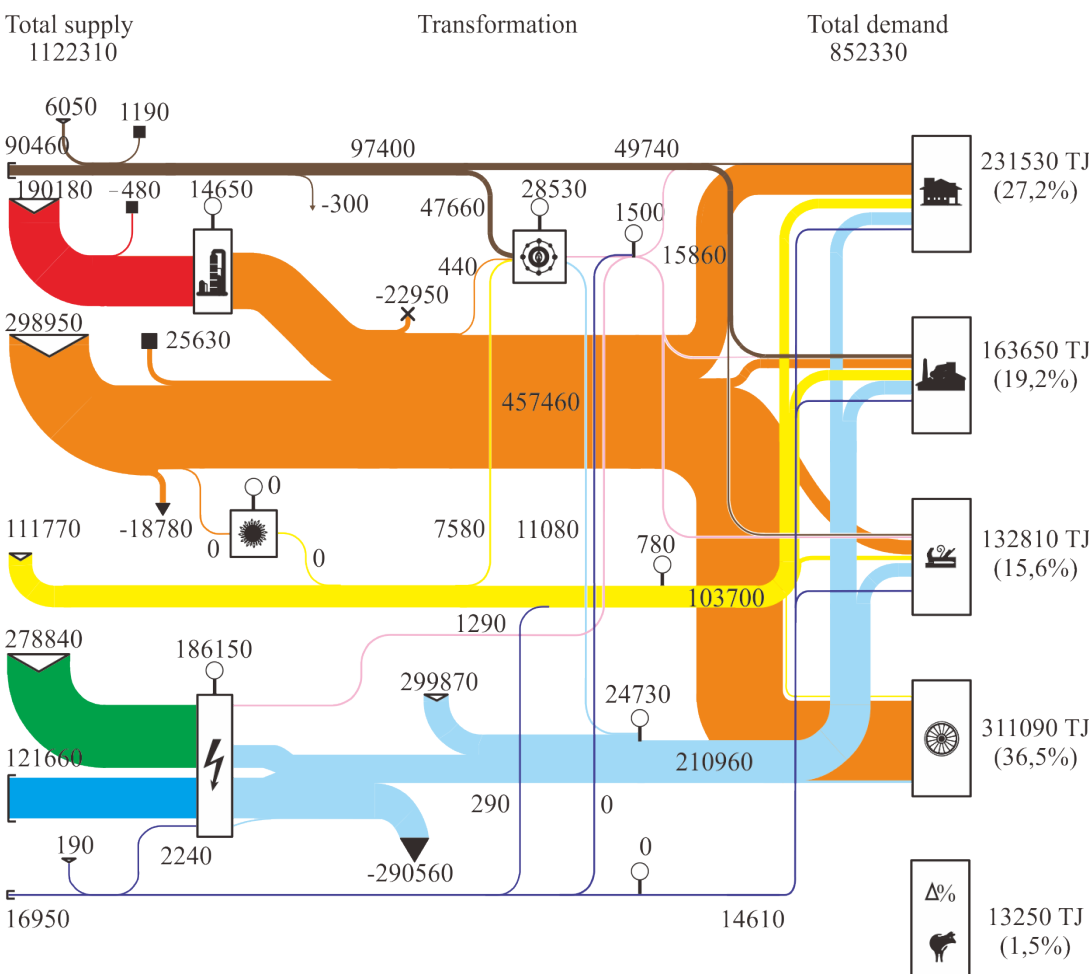
Energy flows TJ
for Switzerland
(2011)

Total Primary
Energy Supply
(TPES)



Population
Energy demand
Area
Density
GDP(PPP)

8'014'000
852'330 TJ
41'285 km²
194/ km²
340 bil. US\$



- Wood/Coal/Waste
- Crude oil
- Petroleum
- Natural gas
- Nuclear fuel
- Hydropower
- New renewables
- Electricity
- District heat
- Refineries
- Hydro/Nuclear
- Gasworks
- Thermal
- Production
- Import
- Export
- Change in stocks
- Losses
- Non-energetic
- Households
- Industry
- Services
- Transportation
- Difference

Image courtesy of Swiss Federal Office of Energy

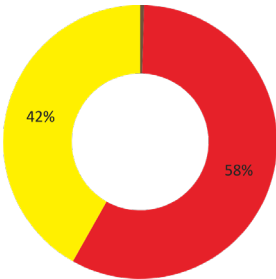


Digital Twin: Energy Singapore

Dr. Matthias Berger, Singapore-ETH Centre, 2012.

Energy flows TJ
for Singapore
(2011)

Total Primary
Energy Supply
(TPES)



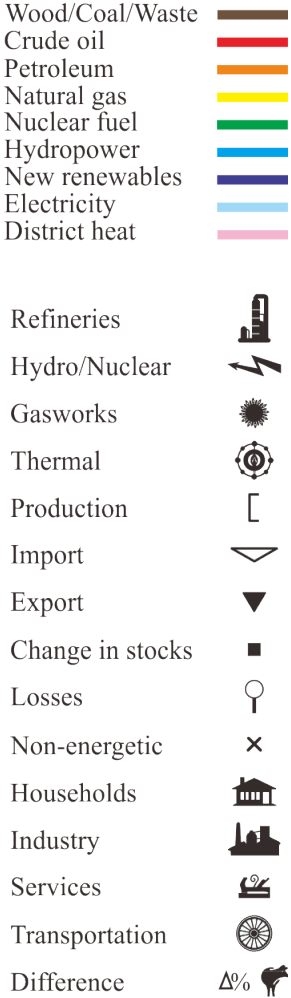
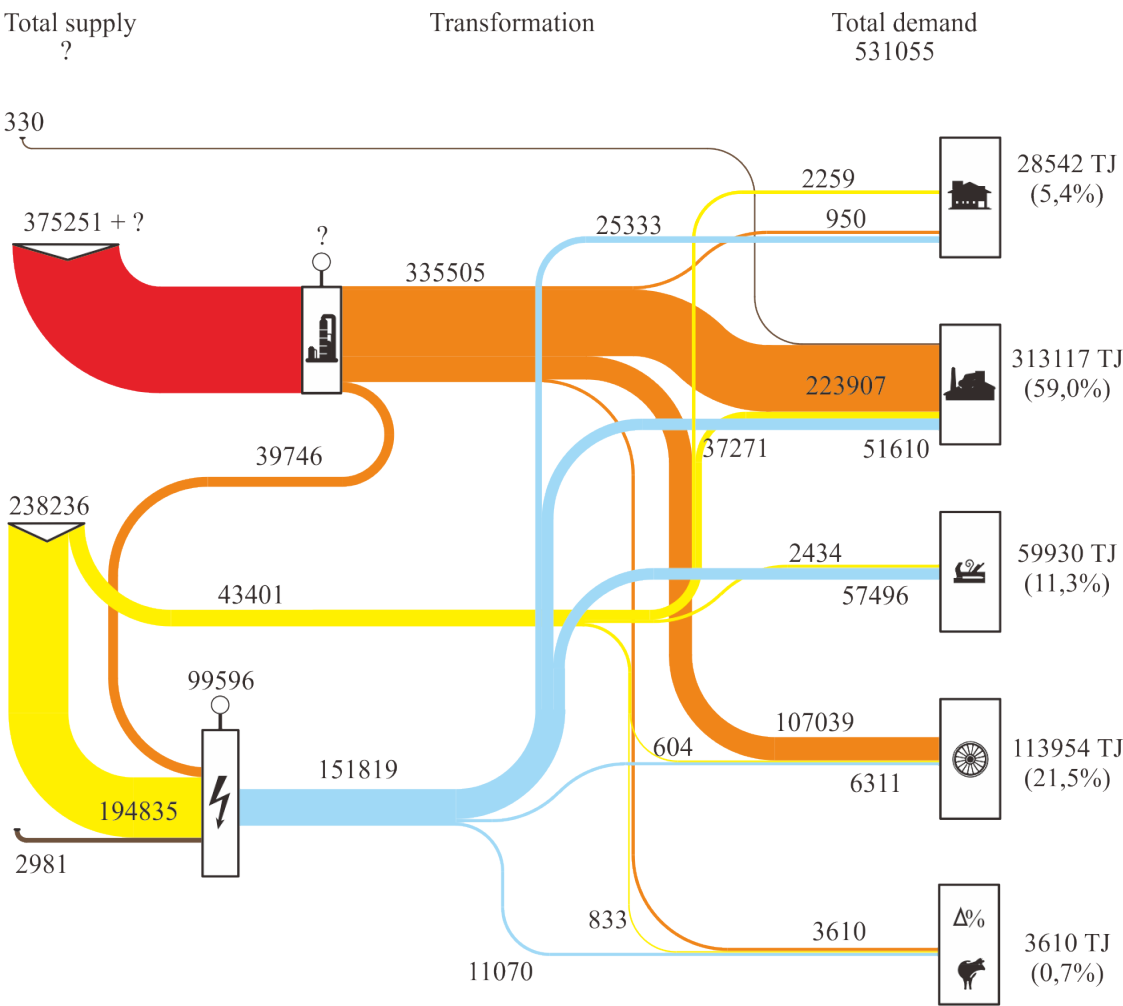
Population 5'312'400

Energy dem. 531'055 TJ

Area 712.4 km²

Density 7126/ km²

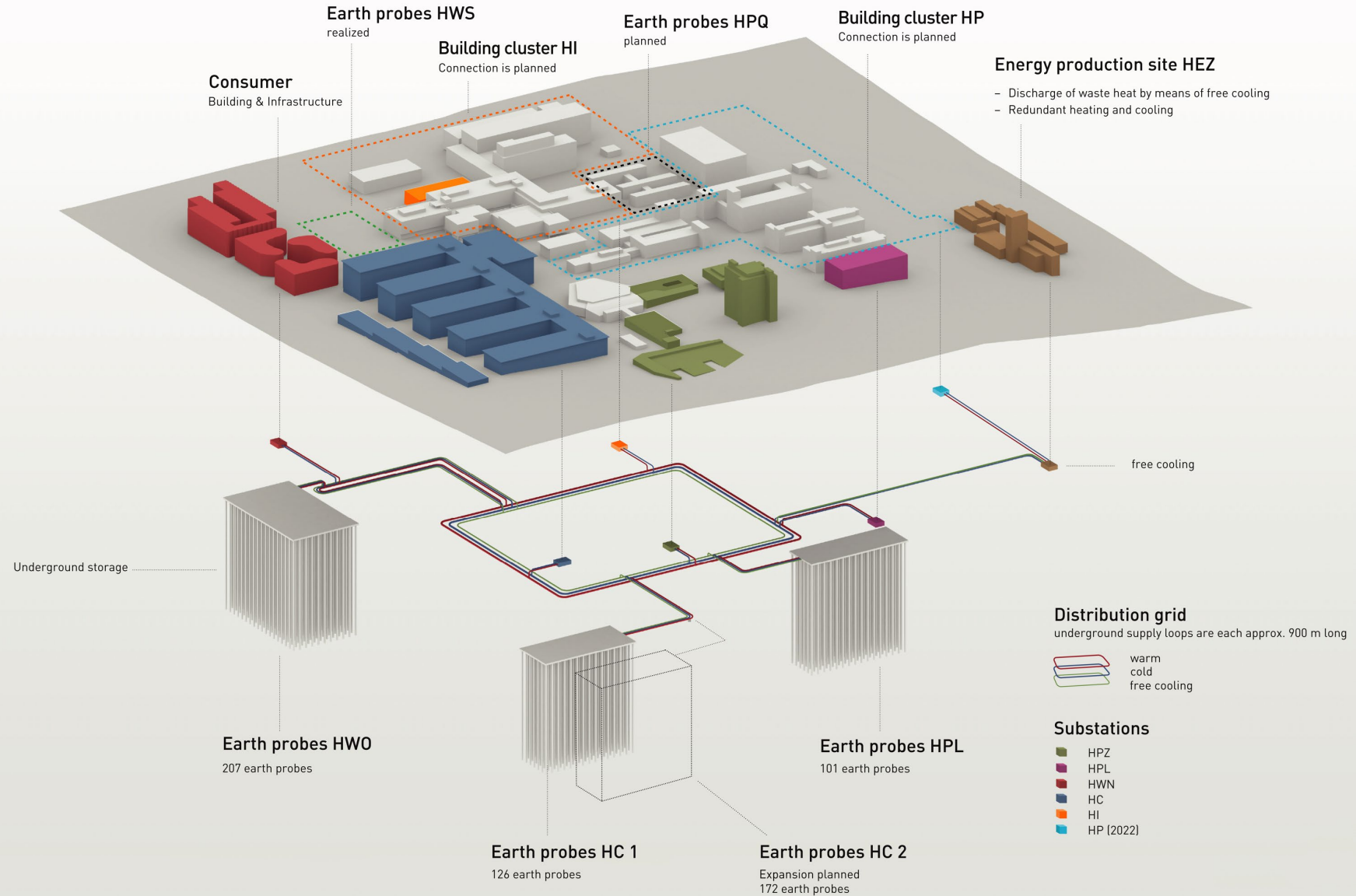
GDP(PPP) 315 bil. US\$

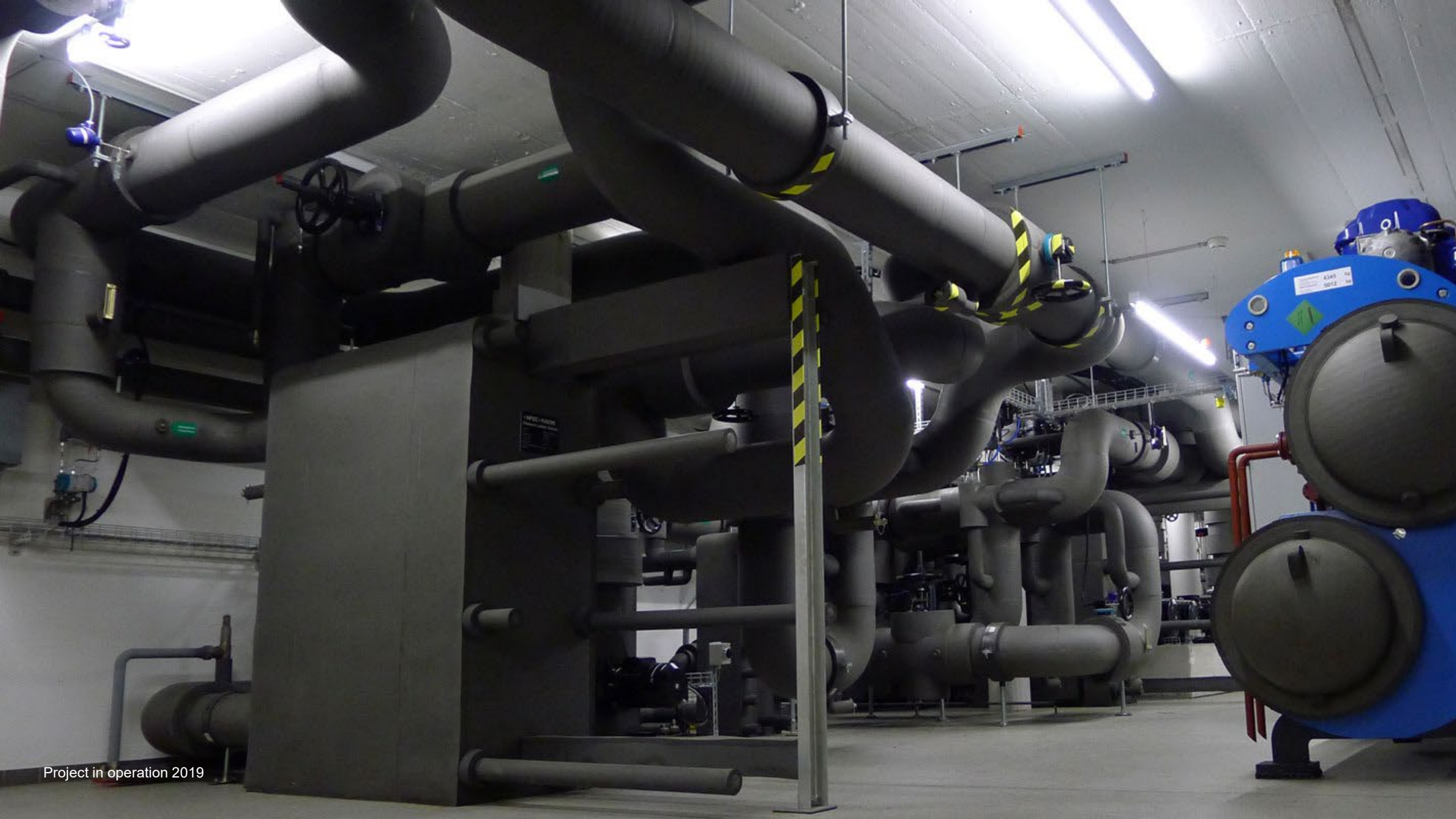


Beyond Sustainable Cities: Generative Cities

ETH Zurich, Campus Höggerberg

Anergy Grid





Project in operation 2019

Towards Sustainable

After 12 Years

Electricity

Production (photovoltaics)

Heating

Dynamic Earth Storage and Heat
Pumps

CO₂

Massive Reduction (>50%)



House in the vineyard, Germany

Towards Generative

After 11 Months

12'400 kWh

Production (photovoltaics)

4'600 kWh

Consumption (household, floor-heating, floor-cooling, e-mobility)

What do these examples have in common?

Designed using
digital twins



Singapore-ETH Centre
CREATE Campus

- ETH Zurich's only major research centre outside Switzerland
- Part of National Research Foundation's Campus for Research Excellence and Technological Enterprise (CREATE)

ETH zürich



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**Thank you to the
Research Team, Partners,
UHI Workgroup,
Scientific Advisory Committee,
Steering Committee,
National Research Foundation,
and ETH Zürich**





Dr Kristina Orehounig, EMPA & SEC
Current Lead-PI (SEC)

COOLING SINGAPORE

Future Urban Climate Design and Management

The COOLING SINGAPORE initiative is an integrated and holistic approach to address the URBAN HEAT CHALLENGE for Singapore and other cities around the world

Cooling Singapore in the News



Bloomberg Global Financial News
Bloomberg Quicktake ✓ 1769 aktive Zuschauer
Bloomberg Global News brings you live coverage of the markets and the news you need to know across business, finance, technology, politics and more.

New & Featured Original Series ▶ ALLE WIEDERGEHEN

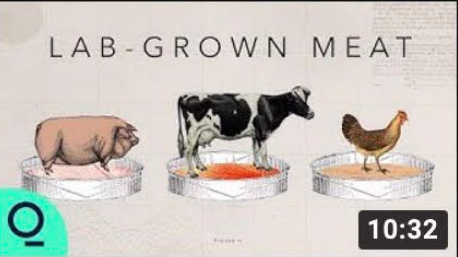
Stay informed with the latest from our global team of video journalists.



How Singapore Uses Science to Stay Cool

Bloomberg Quicktake ✓
738.647 Aufrufe • vor 5 Tagen

Untertitel



No Animals Were Harmed In The Making Of This Meat

Bloomberg Quicktake ✓
89.152 Aufrufe • vor 5 Tagen

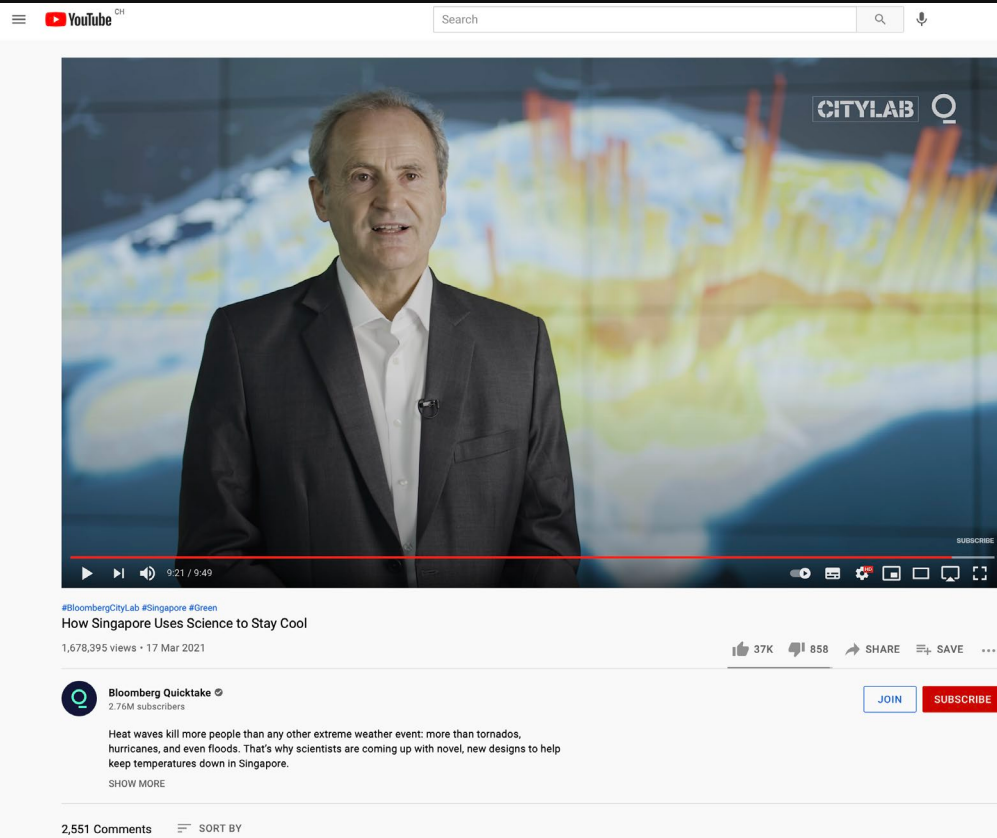
Untertitel



Heroin's Hidden Ingredient, Courtesy of a U.S. Company

Bloomberg Quicktake ✓
226.861 Aufrufe • vor 6 Tagen

Untertitel



Life-Saving Car Technology No One Wants

Bloomberg Quicktake ✓
108.862 Aufrufe • vor 1 Woche

Untertitel

Untangling a Murder Conspiracy in Honduras

Bloomberg Quicktake ✓
58.476 Aufrufe • vor 1 Woche

Untertitel

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SINGAPORE'S URBAN HEAT ISLAND

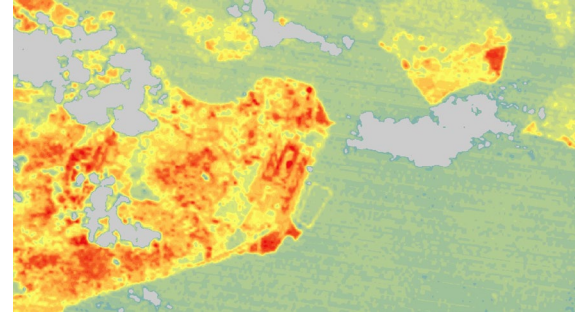






AIRPORT

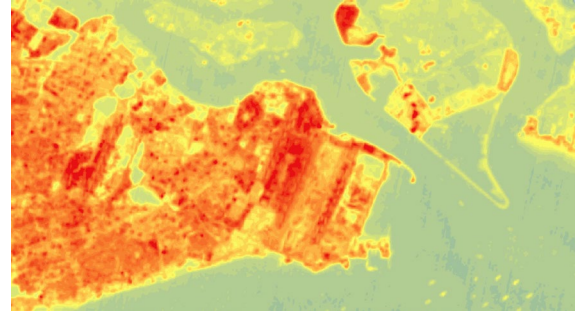
13 September 1989
10:42 am



25 December 2003
10:55 am



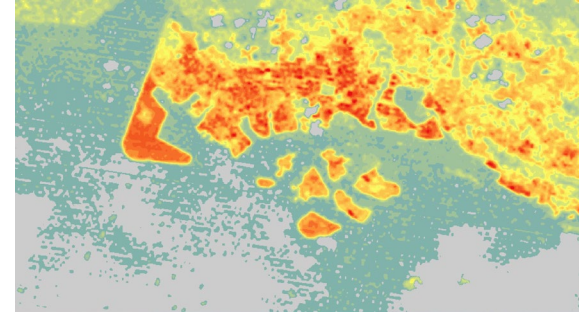
8 May 2018
11.16 am



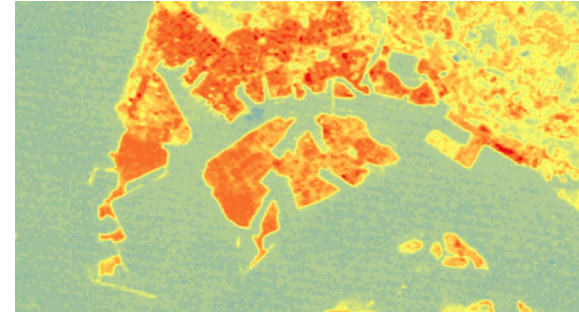
This is work in progress. The surface temperature map can be used as an initial indicator to understand the impact of the building mass.

JURONG

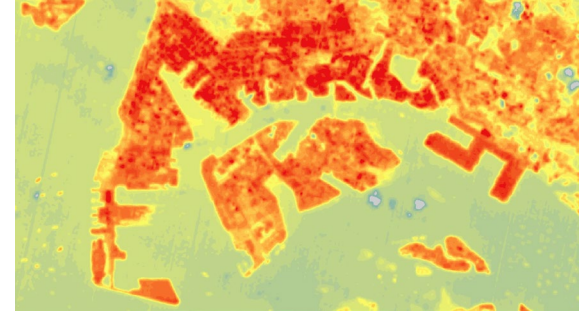
13 September 1989
10:42 am



25 December 2003
10:55 am



8 May 2018
11.16 am



This is work in progress. The surface temperature map can be used as an initial indicator to understand the impact of the building mass.

Passive and Active ANTHROPOGENIC HEAT

**(Mostly Passive)
ANTHROPOGENIC
HEAT**

CLIMATE RESPONSIVE DESIGN GUIDELINES

URBAN GEOMETRY

Sky view factor
Aspect ratio
Mean building/tree height
Building form
Variation between building heights
Wider streets
Air circulation
Open spaces along the shore
Building porosity
Street level vegetation
Well ventilated sidewalks
Building arrangement
Open spaces at road junctions
Guide wind flows with urban elements
Passive cooling systems
Urban density by Local Climate Zones
Building Surface Fraction
Green Plot Ratio
Topography

URBAN GEOMETRY

VEGETATION

Green roofs
Vertical greeneries
Green walls/facades
Vegetation around buildings
Selective Planting
Green pavements
Infrastructure greenery
Macroscale urban greening
Local scale urban greening
Microscale urban greening
Green parking lots
Tree species
Urban farming
Transport corridors

VEGETATION

WATER BODIES

Cool sinks
Blue and green spaces
Wetlands
Water catchment areas
Ponds on roofs/ground floor
Evaporative cooling
Mountain air

WATER SHADING BODIES

Building orientation
Shading on buildings
Permanent shading devices
Moveable shading devices
Smart shading devices
Shaded pedestrian spaces
Shaded bicycle lanes

ENERGY

Heat losses in buildings
Energy efficiency of air-conditioning systems
Energy efficiency of household appliances and office equipment
Energy efficiency of industries
Cooling load of buses
Indoor temperature setting
Sizing of the energy plants
Ventilation for heat base load air conditioning units
Window-to-wall ratio
District Cooling
Renewable energy sources
Heat recovery systems
Mixed used neighbourhoods
Buffer zones
Hybrid ventilation in outdoor spaces

ENERGY

TRANSPORT

Vehicle population
Public transport
Centralised routing system
Active mobility
Electric private vehicles
Electric public transport
Autonomous mobility
Infrastructure for public bus stop
Types of road materials
Material and colour of cars

TRANSPORT

MATERIALS AND SURFACES

Cool pavements
Permeable surfaces
Photocatalytic cool pavements
Cool roofs
Cool facades
Photocatalytic cool building envelope
Retro-reflective materials
Phase Change Materials
Desiccant systems
Water cooling facade system
Thermochromic selective materials
Dynamic and active roofs
Dynamic and active facades or building components
Building envelop performance

MATERIALS & SURFACES

(Mostly Active)
ANTHROPOGENIC
HEAT

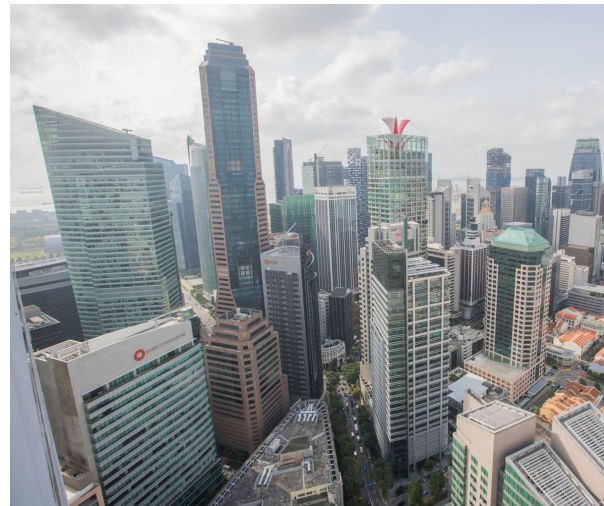
ANTHROPOGENIC HEAT EMISSIONS

Energy consumption from **buildings**

HDB (i.e., public housing)
50 kWh/m² per year

Private housing (e.g., condos)
1.5x more than HDB

Commercial buildings
6x more than HDB



Source: Cooling Singapore (2019)

Energy used by **road transportation**

Lorries / vans
45%

Private cars
30%

Buses
15%

Taxis
8%

Motorcycle
2%

Source: Cooling Singapore (2019)

(left bottom) The Business Times (2017)
(left top) Cooling Singapore, Lina Meisen (2018)
(right top) The Straits Times (2019)



Analysis of the anthropogenic heat

Result #1

Yearly representation of AH sources of Singapore for 2016.

- The AH emissions of Singapore are generated by five key sources:
 - Industry (58.5%)
 - Power generation (15.3%)
 - Buildings (11.9%)
 - Road transportation (11.4%)
 - Human metabolism (2.8%)
 - Excluding aviation and ship.*
- A **Sankey diagram** represents the emissions of Singapore for the year 2016.

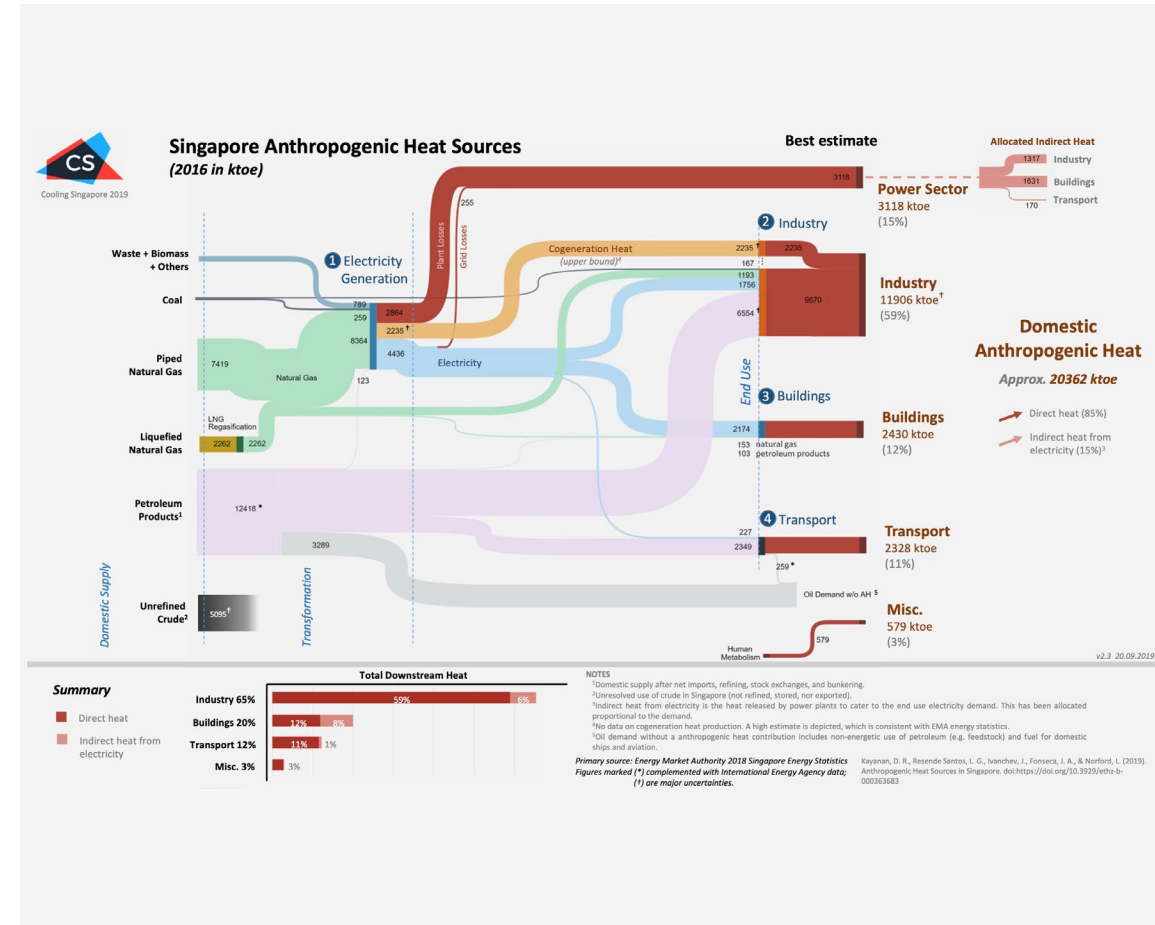
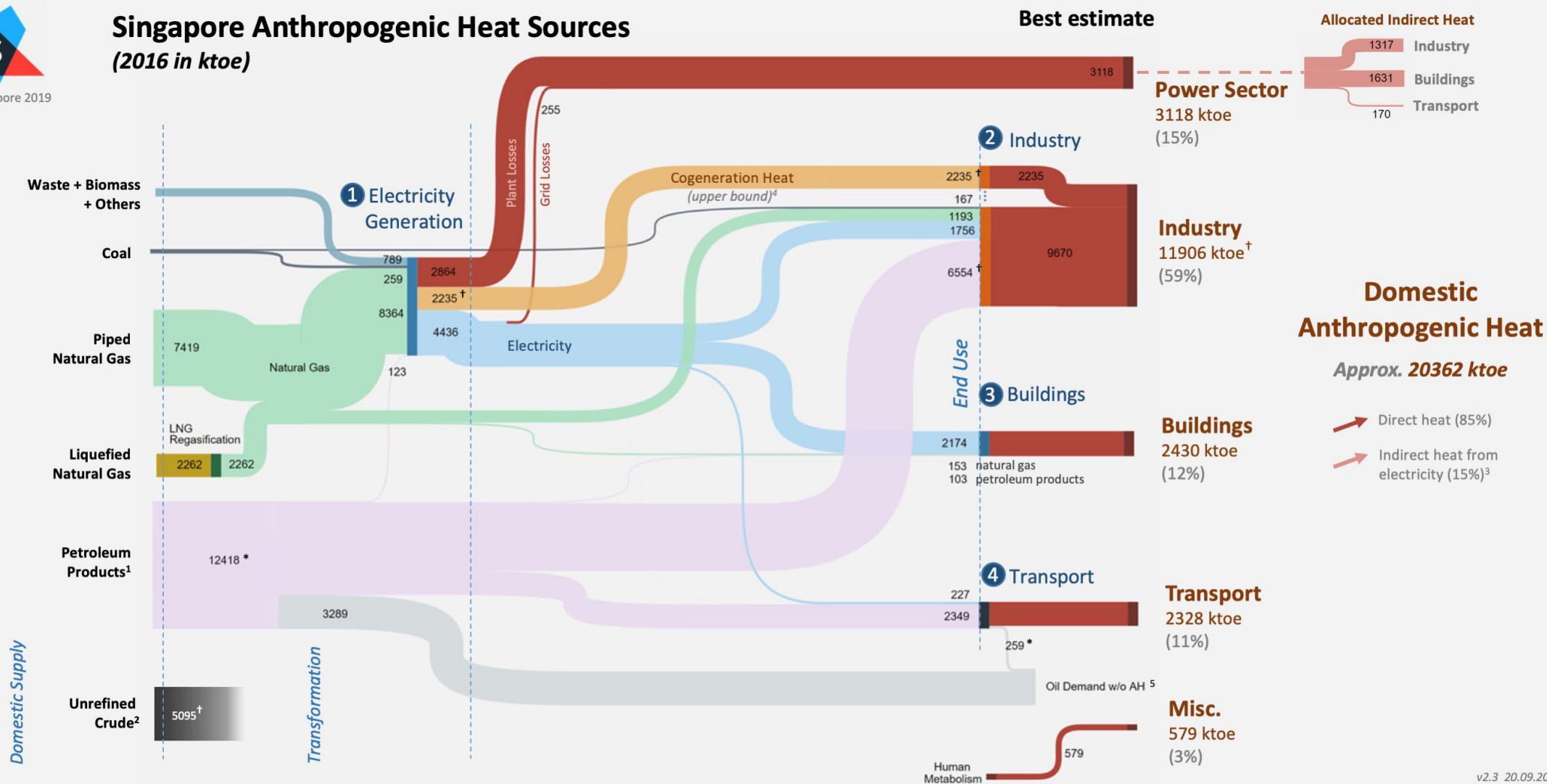


Image: Sankey Diagram | Cooling Singapore, 2019

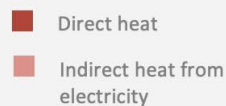
Data: extracted from the public website of the Energy Market Authority of Singapore and the International Energy Agency.

Report: Kayanan, D. et al., 2019. <https://doi.org/10.3929/ethz-b-000363683>

Singapore Anthropogenic Heat Sources (2016 in ktoe)



Summary

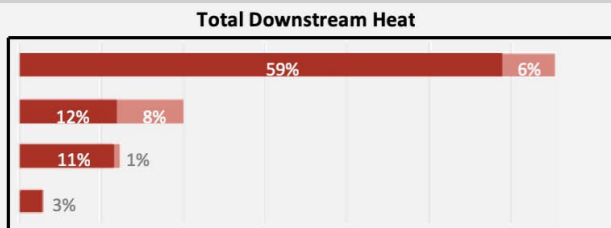


Industry 65%

Buildings 20%

Transport 12%

Misc. 3%



NOTES

¹Domestic supply after net imports, refining, stock exchanges, and bunkering.²Unresolved use of crude in Singapore (not refined, stored, nor exported).

³Indirect heat from electricity is the heat released by power plants to cater to the end use electricity demand. This has been allocated proportional to the demand.

⁴No data on cogeneration heat production. A high estimate is depicted, which is consistent with EMA energy statistics.

⁵Oil demand without a anthropogenic heat contribution includes non-energetic use of petroleum (e.g. feedstock) and fuel for domestic ships and aviation.

Primary source: Energy Market Authority 2018 Singapore Energy Statistics
Figures marked (*) complemented with International Energy Agency data;
(†) are major uncertainties.

Kayanan, D. R., Resende Santos, L. G., Ivanchev, J., Fonseca, J. A., & Norford, L. (2019). Anthropogenic Heat Sources in Singapore. doi:<https://doi.org/10.3929/ethz-b-000363683>

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Digital Urban Climate Twin

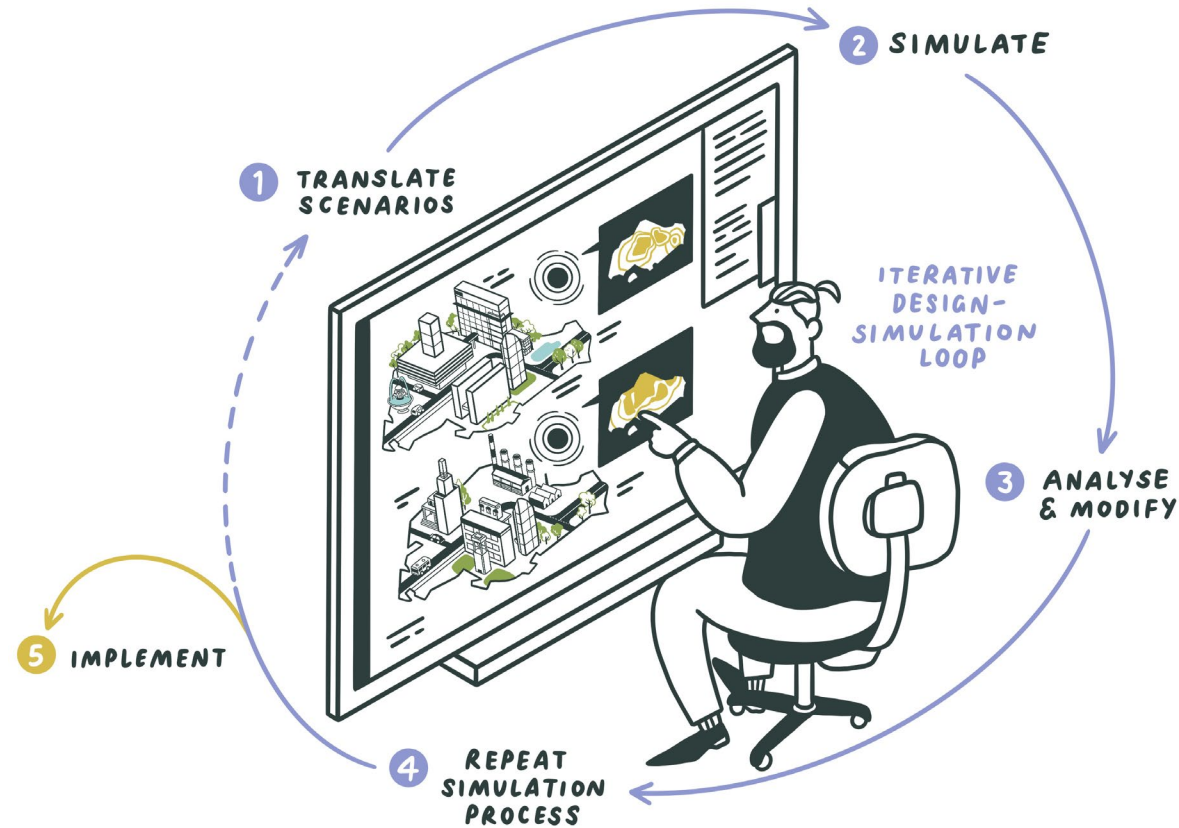
DIGITAL URBAN CLIMATE TWIN

Urban Climate Design and Management

“Urban climate design and management refers to ability to understand the climate science, to modify and maintain the urban climate (temperature, humidity and air-flow) on different urban scales (e.g., island-wide and building-scale), and to comprehend the social science of risks and mitigation to set targets and desired conditions accordingly.”

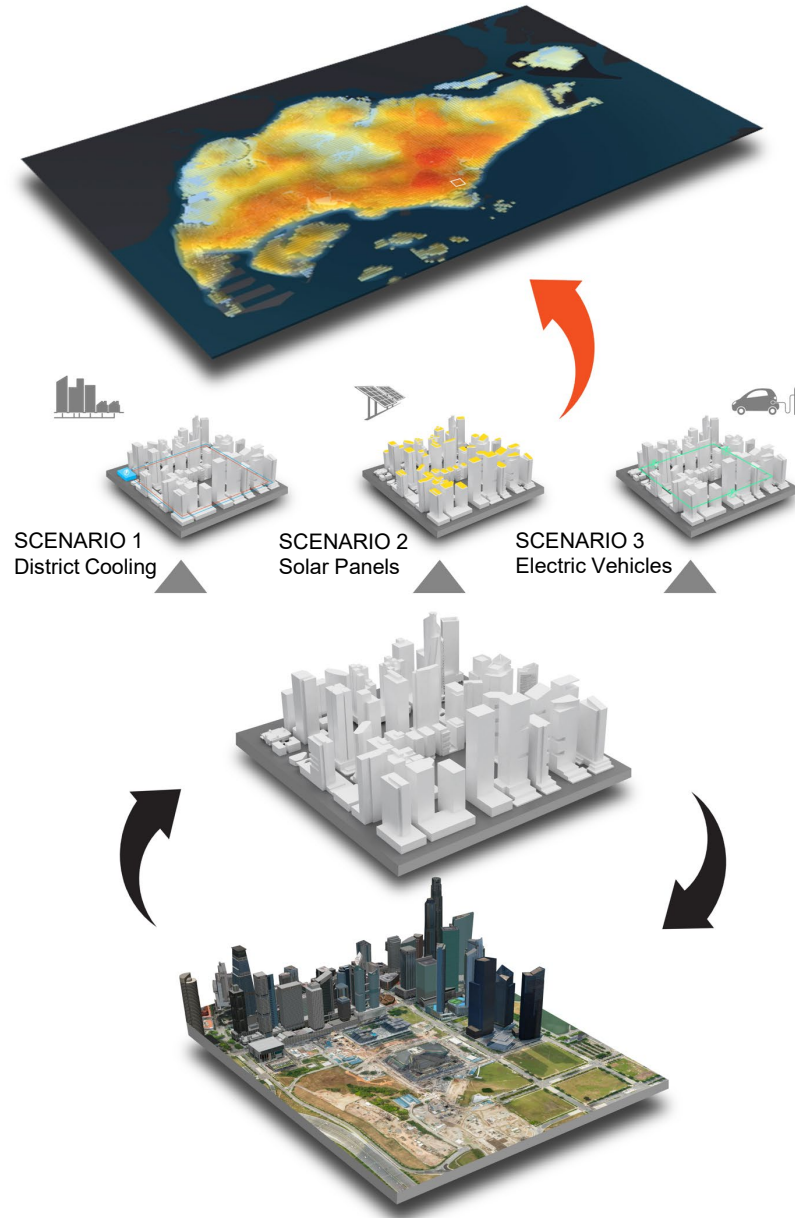
Provide planners and decision makers with a tool (== Digital Urban Climate Twin) that allows them to experiment with what-if scenarios in order to make better-informed decisions.

This will require a lot of computational power...



DIGITAL URBAN CLIMATE TWIN

What-if Scenario Analysis



**MICRO- &
MESOSCALE
SIMULATION**

**WHAT IF
SCENARIO**

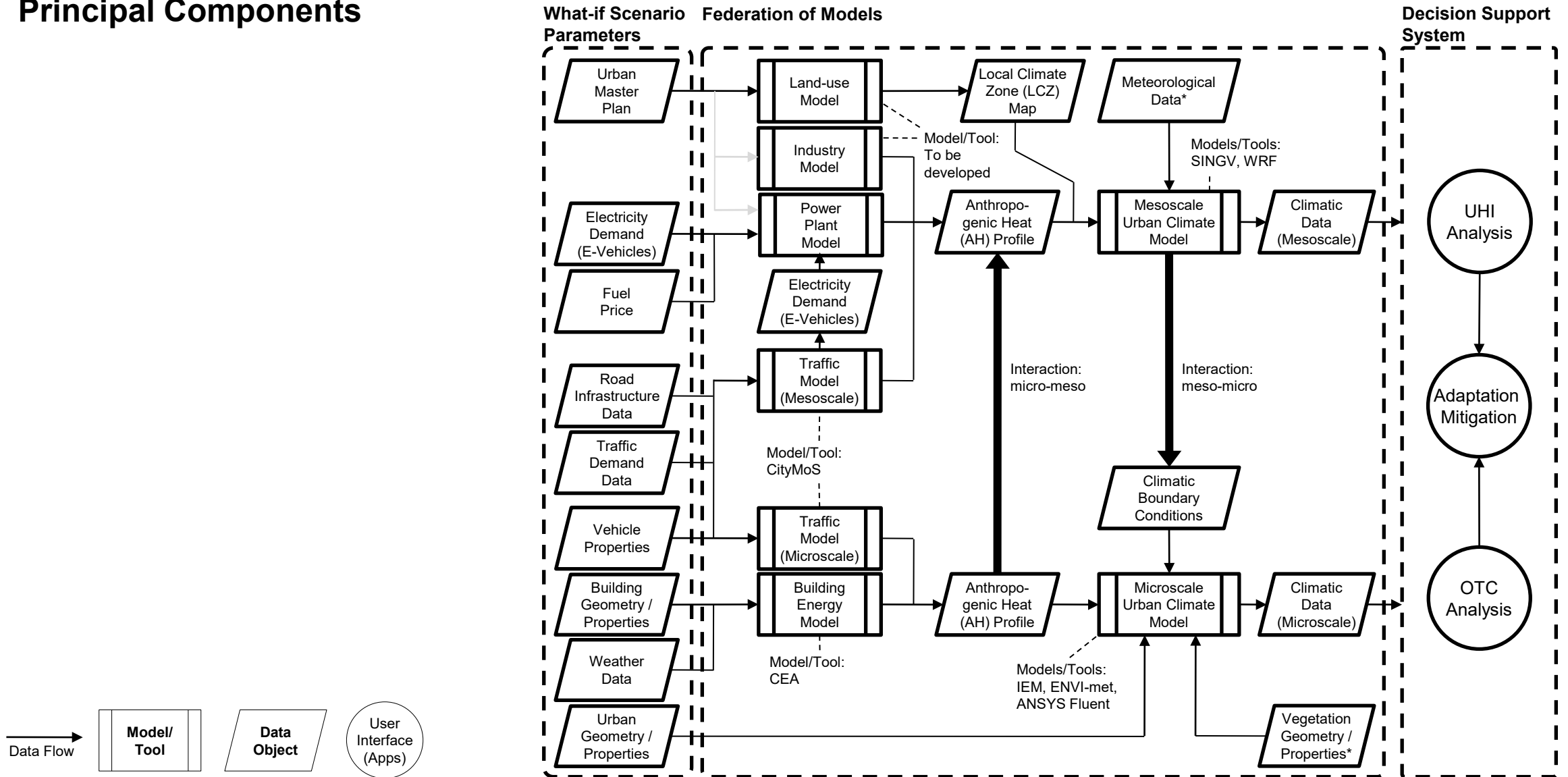
**DIGITAL
TWIN**

**REAL
WORLD**

In reference to Dr. Heiko Aydt, Cooling Singapore

DIGITAL URBAN CLIMATE TWIN

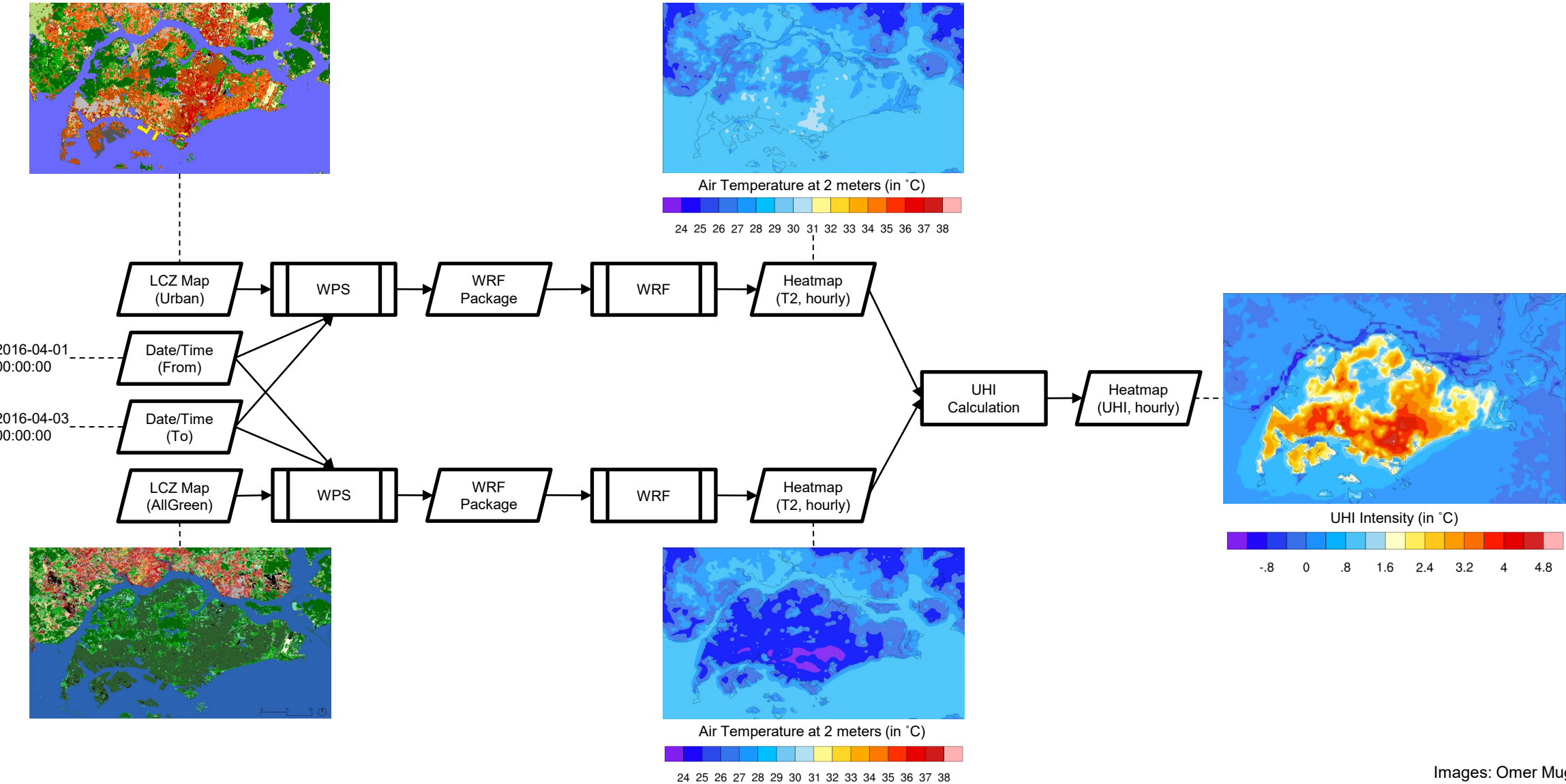
Principal Components



*) part of what-if scenario parameters but shown here for conciseness.

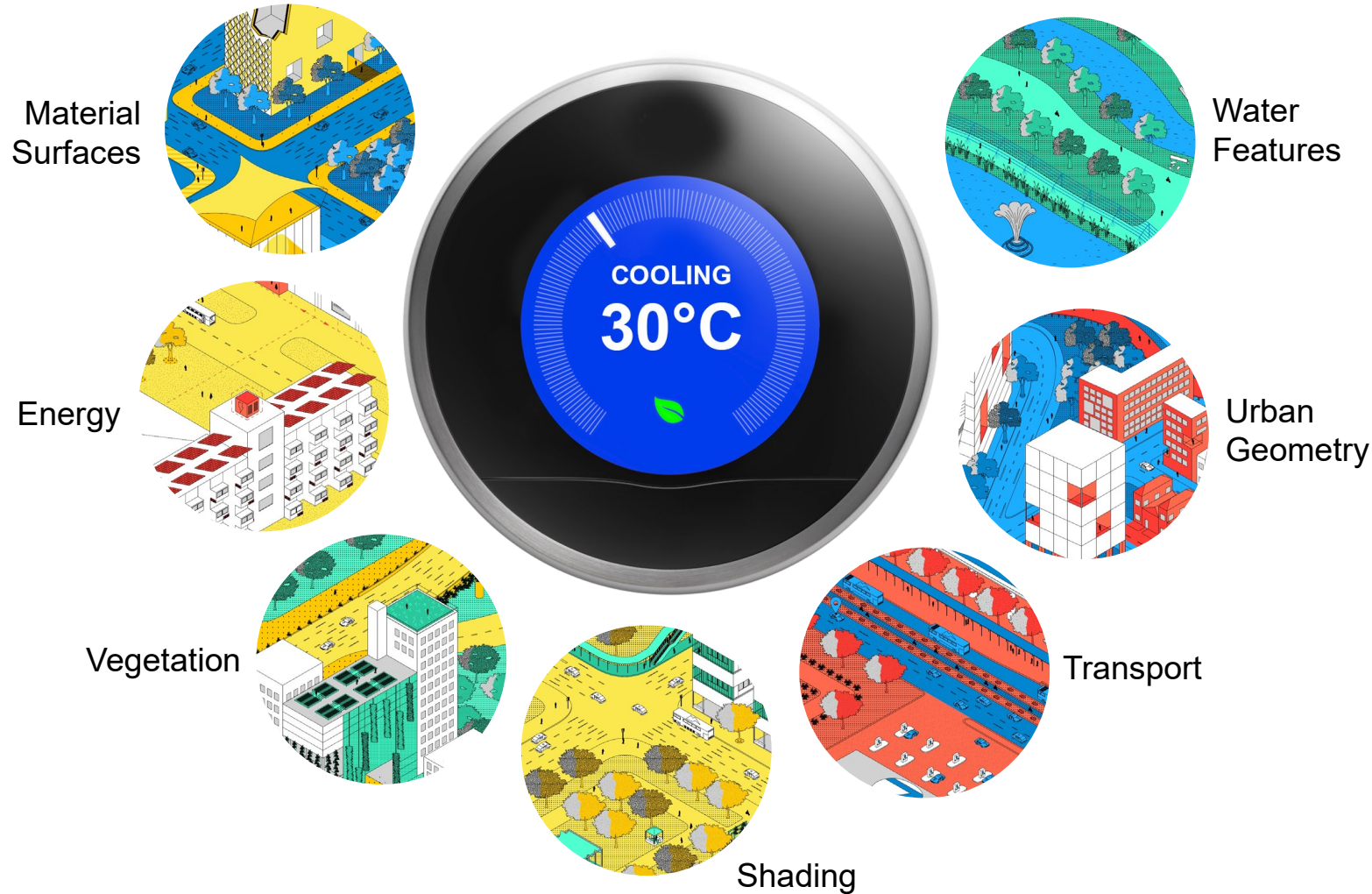
DEMONSTRATOR 1 – WORKFLOW AUTOMATION

Overview



URBAN CLIMATE DESIGN AND MANAGEMENT

MITIGATION AND ADAPTATION



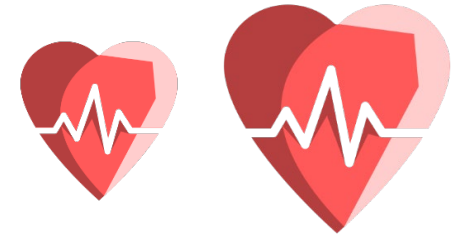
Environment



Economy



Health



Costs



The temperature of 34 degree is based on MSS data where 30.0°C is indicated as the highest monthly mean temperature¹ plus additional up to 4.6 degree (°C) temperature increase through to climate change²

1: Highest Monthly Mean Temperature (°C) / 1929-1941 and since 1948, average over all MSS Climate Station <http://www.weather.gov.sg/climate-historical-extremes-temperature/>

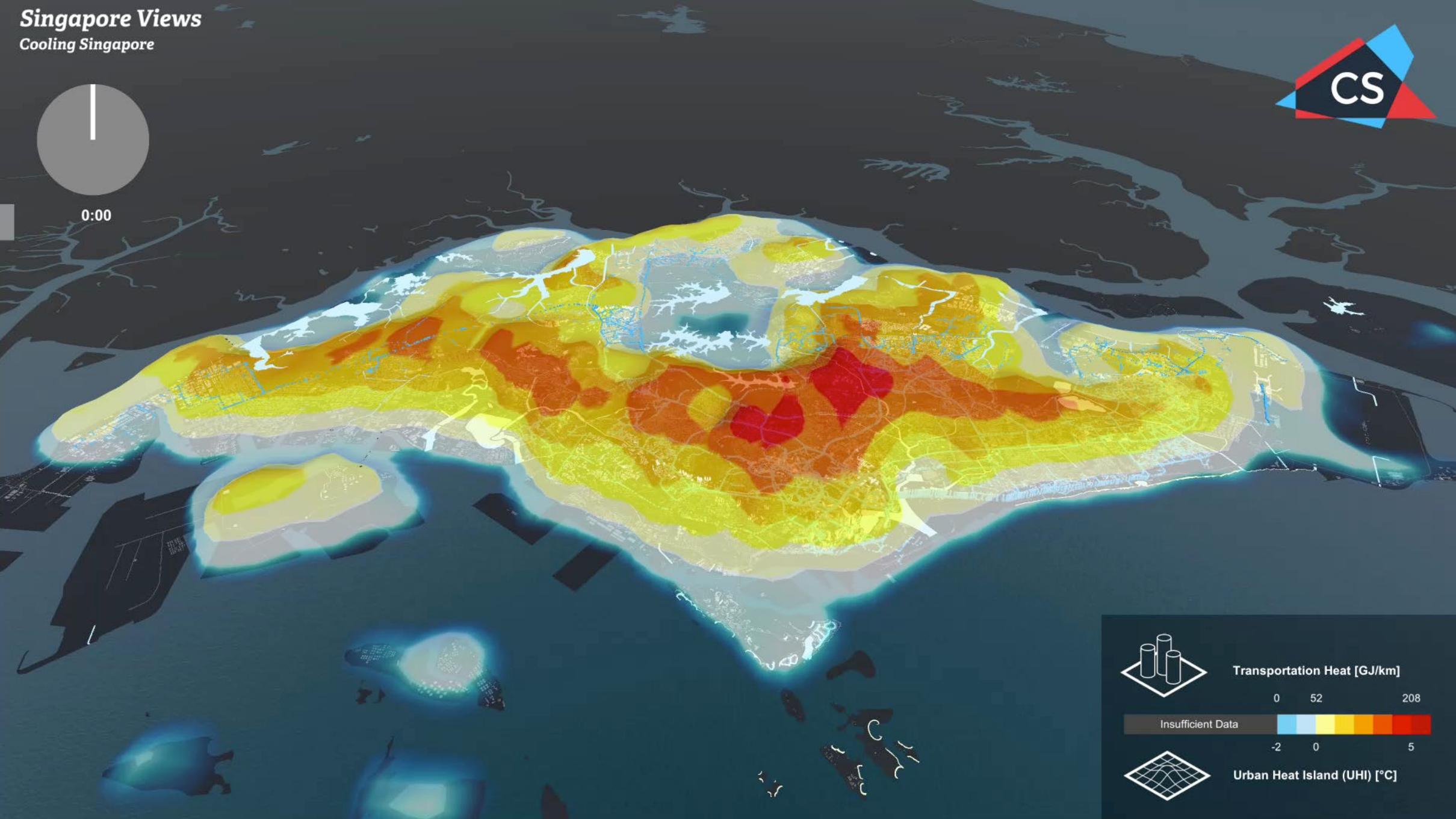
2: <https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-of-climate-change-on-singapore>

Singapore Views

Cooling Singapore



0:00



Transportation Heat [GJ/km]

0 52 208

Insufficient Data

-2 0 5



Urban Heat Island (UHI) [°C]

Conclusion

From the Vision of Generative Future Cities Through Responsive Governance Towards
Generative Enterprises:

Digital Twins as crucial enablers for moving
towards decarbonized, cooler, quieter,
healthier and more resilient cities

A vibrant photograph of a forest in full summer foliage. Large, mature trees with thick trunks and dense, bright green canopies dominate the scene. Sunlight filters through the leaves, creating a dappled light effect on the forest floor. The ground is covered in green grass and low-lying vegetation. The overall atmosphere is peaceful and natural.

Thank you!